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CABBAGE DISEASES

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CABBAGE DISEASES are preventable in the main by simple means of plant sanitation.

Rotation of crops should be practiced, avoiding crops which belong to the cabbage family, such as cauliflower, turnips, Brussels sprouts, and kale. Keep down mustard and related weeds which harbor cabbage pests.

Drainage water and refuse from diseased cabbage fields will carry infection. So will stable manure with which diseased material has been mingled.

The seed bed is often the source of infection. The greatest pains should be taken to insure healthy plants. Locate the seed bed on new ground, if possible, or sterilize by steam the soil used.

Clubroot is avoided by the free use of lime and by setting healthy plants. Disinfect all cabbage seed before planting, to prevent black-rot and black-leg. Yellows is due to a fungus which persists in the soil for many years. Varieties of cabbage resistant to disease are being developed.

This bulletin is a revision and extension of Farmers' Bulletin No. 488, entitled "Diseases of Cabbage and Related Crops and Their Control."

CABBAGE DISEASES.

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CABBAGE AND OTHER CRUCIFERS.

FROM THE ORIGINAL WILD STOCK of cabbage have come cauliflower, Brussels sprouts, kohl-rabi, collards, and kale. Other cultivated plants closely related to those already mentioned are turnips, radishes, rape, broccoli, rutabaga, and charlock. Among the related wild plants shepherd's-purse, peppergrass, and mustard are of most frequent occurrence. Mustard is sometimes cultivated, but it grows so profusely under all conditions that it is perhaps better classed as an obnoxious weed. The term "crucifers" used in this bulletin refers collectively to all the vegetables and weeds mentioned in this paragraph, which belong to the botanical family Cruciferæ, so called from the form of the four-petaled flower. Practically all of them are subject to the same diseases, so that any method for the control of the diseases of cabbage or cauliflower, for example, can be applied to other crucifers as well.

HOW THE VARIOUS DISEASES ARE DISSEMINATED.

Fungous and bacterial diseases are carried from one place to another by various means, such as (1) insects, (2) infected seed, (3) transplanting from an infected seed bed to the field, (4) drainage water, (5) cabbage refuse and stable manure, (6) farm animals and tools, and (7) wind.

INSECTS AS DISEASE CARRIERS.

Insects frequently are distributors of diseases. For instance, the bacteria causing the black-rot of cabbage is carried from one plant to another and from one leaf to another by slugs, snails, etc. Insect wounds offer favorable places for infection with certain diseases. Insects which visit cabbage and other crucifers are likely to carry the germs on their bodies and deposit them on the parts of noninfected plants. If the conditions are favorable, infection then takes place.

Certain insects are attracted to diseased areas of plants by the odors emitted therefrom. Cabbage affected with clubroot has a very offensive odor at some stages in the development of the disease, and this odor has been known to attract insects. New infections may be brought about by these insects visiting other plants.

INFECTED SEED.

Growers of cabbage for the market seldom raise their own seed, but purchase it from seed growers. The same can be said of cauliflower and other related plants. If the seed is grown where diseases are prevalent it is possible that some disease may be introduced with the seed. The germs of some of our worst plant diseases, including the black-rot and black-leg of cabbage, have been found to overwinter on the seed. For this reason it is always advisable, as a precautionary measure, to treat the seed with some disinfectant before sowing. (See pp. 6 and 7.)

TRANSPLANTING.

Plants that are started in a crowded seed bed, which is often located on old ground near the house or in the garden, are frequent carriers of diseases to a noninfected field. In such crowded conditions diseases are readily communicated from one plant to another. Some of the diseases of cabbage and cauliflower, such as clubroot, are known to be distributed to some extent by insects. The insects, burrowing through the ground or feeding upon the roots, carry the disease from the roots of one plant to those of another. The loss in the field can be greatly reduced if care is exercised to prevent the introduction of the disease into the seed bed by proper disinfection of the seed and selection of clean soil or by soil disinfection where rotation is impracticable.

DRAINAGE WATER.

Drainage water or the run-off during heavy rains probably furnishes one of the most important means for the dissemination of plant diseases and has been found in many places to explain the presence of a disease in fields where cabbage or other crucifers have never before been grown. If the crop is planted on high ground the

germs from the refuse of diseased plants may be washed to the low-lying fields during heavy rains. In the hope of avoiding the disease by crop rotation, a new field on this low ground may be selected, where the disease will prove as severe as on the abandoned field.

In some sections where cabbage is grown on a commercial scale it is customary to set the plants with a machine which drops about a half pint of water for each plant. For this purpose the water from drainage ditches, which is often the run-off from a field where some bad disease has been present, being the most available, is frequently used. This use furnishes another method of spreading disease, as was illustrated in a field set to cabbage for the first time, where the water used in setting a part of the field was obtained from a well; for the remainder, water from a drainage ditch adjacent to a field planted to cabbage the previous year was used. The plants set in both portions of the field were secured from the same seed bed. The yellows was very severe where the plants were set with water from the drainage ditch; the other part of the field was free from it.

CABBAGE REFUSE AND STABLE MANURE.

A not uncommon practice is for farmers to throw the refuse of cabbage or other crops on the manure heap, the compost thus formed being hauled out and distributed on the fields the following spring. Near sauerkraut factories the refuse is often spread directly on the cabbage land and plowed under. These are bad practices if the crop is diseased, as the causal organisms may thereby be readily disseminated.

The value of cabbage leaves as fertilizer is doubtful. They contain nearly 90 per cent of water, so that even if all the dry matter had fertilizing value, the quantity is ordinarily so small as to be of minor importance. In any case, the refuse should be plowed under on fields designed for the culture of crops other than cabbage or its relatives.

DISTRIBUTION BY FARM ANIMALS AND TOOLS.

While the use of sheep or other animals in cabbage fields is recommended for saving the waste, it should be remembered that the worst diseases are perpetuated in the stem and root tissues, which are not eaten. On the other hand, grazing animals passing from the cabbage lands to other fields may scatter the germs of cabbage diseases. Many of these germs pass through the digestive tract unharmed, and in any case they are easily carried with the soil on the feet of animals. A reasonable amount of care, therefore, should be exercised so that infected soil will not be transported to new cabbage fields by cultivators and similar tools and by draft horses. While such matters are in some degree unavoidable in farm opera-

tions, these facts should always be understood and all reasonable precautions taken to avoid them, especially with such serious soil-borne diseases as clubroot and yellows.

DISSEMINATION BY WIND.

Dissemination by wind is perhaps not so important a factor in the distribution of diseases of cruciferous plants as some already mentioned. Nevertheless, in certain districts where the soil is light, where dry weather prevails a part of the year, and high winds are common, spores may be carried long distances. The diseases that are external to the leaves are more likely to be distributed in this way than parasites which are situated in the soil or in the internal portion of the plant.

FARM PRACTICE AND ITS RELATION TO THE CONTROL OF DISEASES.

Several methods by which diseases may be carried from one plant to another, from one field to another, or, indeed, from one part of the country to another have already been pointed out. In view of these facts the first aim of the farmer should be to prevent, if possible, the introduction and distribution of destructive diseases on his farm. In order to accomplish this, several precautions should be observed, of which the more important are (1) the disinfection of seed, (2) the location and care of the seed bed, and (3) crop rotation.

DISINFECTION OF SEED.

American cabbage growers, as a rule, prefer to buy seed rather than grow their own, and, in general, this custom is based on sound economic principles and will continue. Seed growing is an industry in itself, requiring specialized cultural methods and certain favorable climatic conditions. Because of these facts most of the American supply of cabbage seed is grown on Long Island or near Puget Sound, or is imported. Those engaged in this seed-growing industry are, as a rule, not well informed about most cabbage diseases and use no special precautions to insure the production of seed free from the germs of disease. Certain diseases, including black-rot and black-leg, develop on seed plants and are disseminated with the seed, and probably nearly all the other disease parasites discussed in this bulletin may do so under some conditions. It is therefore probable that disease germs are being distributed with the seed very commonly. Fortunately, the cabbage grower may easily guard against this danger by the disinfection of his seed before sowing. The process is simple and safe and is applicable to cauliflower, turnip, and other crucifers, as well as to cabbage.

Use 1 ounce of formaldehyde (40 per cent) to 2 gallons of water, or 1 teaspoonful of formaldehyde to a teacupful of water. Soak the seed 15 to 20 minutes in this solution, dip in clear water to wash off the formaldehyde, and then spread out in a thin layer to dry, stirring if needed. There is no danger of injury from slight modifications in either the strength of the solution or the length of immersion provided the seed is well washed and quickly dried after treatment.

LOCATION AND CARE OF THE SEED BED.

Cabbage, cauliflower, and some other plants of the same family are generally started in a seed bed before being set in the field. As previously pointed out, some of the worst diseases of these crops may be transferred to noninfected fields by means of the plants from the seed bed. In order to grow strong, vigorous plants as quickly as possible, compost or stable manure is applied liberally to the seed bed. The mistake is often made of placing the bed on an old cabbage field where diseases may have been present, because the soil happens to be fertile or for other reasons. Furthermore, the manure might be, and often is, taken from the heap where diseased plants have been thrown to compost, or it may be from animals that have fed on diseased cabbage. In either case there would be great danger of introducing the diseases into the seed bed. The transfer of such plants to the field would naturally mean the transfer of the diseases affecting them. To avoid this danger, always make the seed bed on new soil, if possible. Where it is necessary to use old soil which may contain germs, it should be disinfected.

Mr. W. W. Gilbert, of the Bureau of Plant Industry, recommends the following methods for disinfecting the seed beds: Sterilization (1) by means of draintile laid in the bottom of the beds, through which steam is passed; (2) by means of an inverted pan under which steam is admitted, or (3) by drenching the soil with a formalin solution.

In the tile method of steaming, lines of 2-inch to 3-inch glazed tile are placed lengthwise in the beds to be sterilized, 2 to 2½ feet apart and 15 inches below the surface, and are left there permanently. They provide drainage for the beds, may be used for subirrigation, and are available at any time for sterilizing the soil, the only outlay for labor being the covering of the beds with boards or a tarpaulin and the connecting of the tile with a boiler by means of a piece of steam hose. The soil need not be moved, and thus a large part of the labor involved in sterilization is obviated. It is advisable, however, to spade up the soil, so that the steam may more readily penetrate it.

Another method of steaming, by means of an inverted galvanized-iron pan, 6 by 10 feet and 6 inches deep, under which steam is ad-

mitted, has been used in the sterilization of tobacco seed beds and in greenhouse beds and has given very satisfactory results. The use of steam at a pressure of 80 to 100 pounds and treatment for half an hour to an hour after the soil has reached a temperature of 212° F., as indicated by soil thermometers, has given the best results.

Formaldehyde sterilization is accomplished by drenching the soil with a 1 to 100 or 1 to 200 solution of standard formaldehyde (40 per cent), at the rate of three-fourths of a gallon per square foot of area, several days before the soil is to be used. Formaldehyde, however, does not rid the soil of nematodes, as steaming does. This method has been used to good advantage in the sterilization of lettuce beds for the prevention of fungous diseases. Detailed directions for soil sterilization by the methods here outlined will be found in Farmers' Bulletin No. 736, entitled "Ginseng Diseases and Their Control."

CROP ROTATION.

Crop rotation is an essential practice, whether or not it is necessary in the control of any plant maladies. There are numerous fungous diseases which reappear year after year on the same field if a suitable host is present. Some of them, such as the clubroot of cabbage, are strictly soil parasites and can not be controlled by any fungicide. About the only method left to get rid of the organism is to starve it out, and this can be done only by a well-planned system of crop rotation. Most of the organisms like the clubroot of cabbage have a number of hosts on which they live, any one of which will serve to perpetuate the disease. It is therefore necessary to avoid planting in close succession crops that are affected with the same parasites. The length of the rotation depends largely upon the disease and the thoroughness with which the system is carried out. There are only a few diseases that will be killed out by a three or four year rotation, and instances are known where one of six or more years has failed to eradicate the malady, though its severity was greatly reduced. There are several reasons why long rotations are frequently necessary. (1) Many weeds which are overlooked by the farmer during cultivation perpetuate the diseases. (2) Certain parasites are able to live for a time on decayed vegetable matter when a suitable host is not available. Just to what extent this is the case is not always known. (3) Some fungi have the ability to remain dormant for a considerable length of time in the absence of a suitable host. The organism causing cabbage yellows, for example, has been known to be dormant in dry soil for three and one-half years and then to produce the disease. For ordinary practice, however, a rotation of four or five years is sufficient to reduce greatly the loss from most parasites. Deep and frequent cultivation, by means of which the organisms are exposed to the air and sunshine, assists in exterminating them.

FUNGICIDES.

The leaf diseases of cabbage, cauliflower, and related crops are relatively so unimportant that spraying is seldom required. The most important diseases are internal or soil parasites, which are out of the reach of fungicides.

IMPORTANT CABBAGE AND CRUCIFEROUS DISEASES.[1]

The following is a classification of the most important diseases of cabbage and cruciferous plants, with the pages of this bulletin on which they are discussed:

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DISEASES OF THE ROOT:	
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Drop	27
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Malnutrition	23
DISEASES OF THE LEAF ONLY:	
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White-rust	26
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Damping-off	29

CLUBROOT (CLUBFOOT, FINGER AND TOE).

Description.—Plants affected with clubroot, even in the presence of abundant moisture, show in the earlier stages a wilting of the foliage in the sunshine, with recovery toward evening or when cloudy weather comes on. They are characterized by malformations of the roots in the form of swellings (fig. 1), sometimes as large as two fists. Few or no lateral feeding roots are formed. The disease generally attacks the plants when young, often in the seed bed, and plants so affected have a stunted, sickly appearance. Diseased plants seldom grow to maturity. The clubroot of crucifers might be confused with root-knot, which is characterized by similar enlargements of the roots caused by a minute eelworm, or nematode. The malformations caused by nematodes, however, are usually not so large. While present to some extent in the North, especially in greenhouses, root-knot is more commonly met with in the South.

[1] Various names are often applied to the same disease, as shown in this classification.

FIG. 1.—Enlarged roots of cabbage caused by the clubroot organism.

Control.—The clubroot organism is a soil parasite, and for that reason recourse must be made to some form of soil treatment. The organism thrives best in an "acid" soil, and in view of this fact slaked lime at the rate of about 75 bushels per acre added every few years will keep the disease in check. The lime should be added some months before planting. If the crop is to be planted early in the spring the lime should be applied the previous fall, but if a late planting is desired it can be put on in the spring.

Seedlings are very susceptible to the disease, and the utmost precaution must be taken to grow the plants on uninfected soil, or disinfection of the seed bed should be practiced. Furthermore, diseased plants should be destroyed by burning and should not be thrown on the manure pile or left in the field. Crop rotation should be practiced; and, as it has been found that the disease will live in the soil for several years, the rotation should be a long one. All cruciferous weeds should be destroyed, and no cultivated crucifers should be used in the rotation. The disease has been found in this country on cabbage, cauliflower, rutabaga, turnips, radishes, Brussels sprouts, and mustard among the cultivated plants and on some of the weeds of the same family. It probably occurs on many others.

No variety of these crops is known to be positively resistant to clubroot, though the Hollander variety of cabbage is claimed by some growers to be partially resistant. It has also been observed that the varieties of blue or red cabbage are less susceptible to clubroot than the Succession variety. Unfortunately, however, though apparently more resistant, these colored types are not good for all commercial purposes as, for example, the manufacture of sauerkraut.

Distribution and loss.—Clubroot has been known in Europe for more than a century. It occurs in England, Holland, Russia, and other European countries. Its presence in Australia has been known for a number of years. It has also been reported from New Zealand

and from 20 States in this country and probably occurs in many more. It is present over most of the country east of the Mississippi River. In some seasons, from 40 to 50 per cent of the crop in the affected fields is lost by this disease.

Cause.—Clubroot is produced by the invasion of the roots by a slime mold,[1] one of the lowest forms of life. At one time insects were suspected to occasion this disease, largely because they were frequently present in the swellings of the roots. It is now known that they are attracted by the odor of the decaying roots. The slime mold causing clubroot is composed of a mass of motile protoplasm within the roots of the plants. Later it breaks up into numerous fruiting bodies, or spores. The spores then germinate and the content escapes as several irregular masses of protoplasm, each provided with a whiplike appendage. When they come in contact with the proper host they enter the tender roots and form the disease anew.

ROOT-KNOT (NEMATODES).

Description.—Some confusion is likely to result in trying to distinguish between root-knot and clubroot. While the organisms causing the two diseases are quite different, the effects produced on the roots bear some points of resemblance. (Compare figs. 1 and 2.) Root-knot, as a rule, is characterized by smaller swellings than clubroot, more of the lateral feeding roots are affected, and the nodules are located nearer the tips of the roots. If upon breaking open the swellings on the roots pearly white bodies about the size of a pinhead are found, root-knot is to be suspected. These white specks within the swellings are the enlarged egg-bearing female eelworms, which cause the disease. The interior mass of clubroot is slightly pinkish or

FIG. 2.—Enlarged roots of cabbage caused by nematodes.

[1] *Plasmodiophora brassicae* Wor.

brick colored. Root-knot affects a great variety of unrelated plants, while clubroot, so far as known, occurs only on crucifers.

Furthermore, root-knot is confined largely to the light, sandy soils in the South, although it may occur in the Northern States.

Control.—Crop rotation has been found to be a most effective means of controlling this disease, the object being to use crops immune to root-knot for the purpose of starving out the worms. When this method of eradicating the disease is employed, a rotation of at least three years, accompanied by clean cultivation, should be practiced. There are some 480 different species of plants already known to be susceptible to root-knot, among which are many cultivated plants and numerous weeds. Crops known to be immune or highly resistant to the disease that can be used in the rotation are corn, winter oats, rye, timothy, pearl millet, sorghum, wheat, crab-grass, the Iron and Brabham cowpeas, velvet beans, peanuts, and beggarweed. Some of the cultivated crops susceptible to the disease and, therefore, to be avoided in the rotation are alfalfa, vetch, soy beans, cowpeas (except the Iron and Brabham), clover, tomatoes, cotton, okra, cucumbers, cantaloupes, watermelons, celery, beans, sweet potatoes, tobacco, potatoes, peaches, figs, mulberries, and all crucifers.

If the disease occurs in the seed bed or greenhouse, the soil should be sterilized by live steam in accordance with one of the methods referred to on pages 7 and 8.

Distribution and loss.—Nematodes on different crops have been found widely distributed, but more especially in tropical and subtropical climates. Their greater abundance in warm climates indicates that they are natives of the Tropics, and when found in the colder climates they have probably been introduced. The total loss caused by nematodes is very great, much more than is generally appreciated.

Cause.—Root-knot is caused by a parasitic eelworm (*Heterodera radicicola* (Greef) Müll.) one-twentieth to one-sixtieth of an inch in length. It penetrates the small roots and causes irregular swellings of various sizes. The nematode enters the roots in the larval stage. It then becomes motionless and gradually enlarges. After its entrance into the host, changes take place, the male retaining the worm shape and the female becoming pear shaped. Each female lays several hundred eggs. Under favorable conditions a full life cycle can be completed in about four weeks. Nematodes migrate slowly in the soil, the distance covered in a single year probably not amounting to more than 1 or 2 yards. They are dependent upon foreign agencies for means of wide distribution. Nematodes probably pass the winter in the soil in the larval stage, though it is claimed that they winter in the roots of perennial plants in the mature stage. For a fuller discussion of this subject see Farmers' Bulletin 648, entitled "The Control of Root-knot."

BLACK-ROT (BROWN-ROT, STEM-ROT, DRY-ROT).

Description.—Of the symptoms of the black-rot, Dr. Erwin F. Smith says:[1]

The disease may appear in the plant at any stage of growth and is characterized by the following symptoms: Dwarfing, or one-sided growth of the heads, or, if the disease is very severe and has begun early in the season, by the entire absence of any heads, and in extreme cases by the death of the plant. Occasionally the heads rot and fall off, but this is not a necessary consequence, the soft, bad-smelling rot being due to the entrance of other organisms. If the stumps of affected plants are broken or cut across, a brown or black ring (fig. 3, *a*) will be observed, corresponding to the woody part of the stem, this part of the stem being especially subject to the disease. In bad cases this blackening may be easily traced upward into the center of the head and is generally worse on one side.

FIG. 3.—Black-rot: *a*, Section through a cabbage stem, showing the conspicuous ring of black bundles caused by the black-rot organism; *b*, infection through the veins at the margin of a leaf; *c*, a cabbage leaf, showing the blackening of the veins as a result of the invasion of the black-rot organism.

Infection usually takes place at the margin of the leaf (fig. 3, *b*). The progress of the disease from the point of infection can frequently be traced through the veins of the leaf (fig. 3, *c*) by the blackening of the bundles. The marginal infection is later followed by a browning and drying up of the infected areas of the leaf.

Control.—It is to be regretted that no sure methods for controlling black-rot are known, but the observance of certain precautions will prevent serious loss from this very destructive disease. (1) The germs are known to be carried on the seed; therefore, all seed should be disinfected before sowing, in accordance with the method described on page 7. (2) Care should be exercised in the preparation of the seed bed, and only manure and soil should be used that are known to be free from the disease. (3) Crop rotation, whether for the prevention of disease or not, is always a good practice. In

[1] Smith, Erwin F. The black-rot of the cabbage. Farmers' Bull. 68, pp. 5–6. 1898.

connection with black-rot it is very important. To control the disease by this method the rotation should be one in which no cultivated crucifers or cruciferous weeds are allowed to grow in the ground for four or five years. (4) Insects, slugs, snails, etc., by crawling from infected to noninfected plants carry black-rot organisms; when possible, they should be kept in subjection. (5) Live stock should not be allowed to roam at will over diseased cabbage patches, as they may carry the organisms to noninfected fields. (6) Diseased plants as soon as detected should be pulled up and destroyed and not thrown on the manure heap to compost.

Distribution and loss.—Black-rot has been reported from many States east of the Mississippi River and from a few west of it. For 20 years or more it has been destructive in the States of Ohio, Wisconsin, Michigan, and New York. In recent years several other States, particularly Virginia, Iowa, New Jersey, and Texas, have reported outbreaks. The disease has been injurious to cabbage as far south as Florida, and extends through all the States north into Canada. In 1908 it was reported from the State of Washington, but it has not occurred to our knowledge in any of the Rocky Mountain States with the exception of Colorado and Arizona. It is also well known in almost all parts of Europe and has been reported from the islands of Cuba, Porto Rico, and New Zealand.

The loss to cabbage and related plants from black-rot probably exceeds that of any one of the other diseases. It does not end in the field. It often happens that an apparently sound head is found to be rotten inside. The difficulty of detecting such heads and the fact that some are overlooked in handling result in placing many in storage, where they further decay.

Cause.—Black-rot is caused by a yellow bacterium.[1] Infection takes place through the leaves and occasionally through the roots. When infection takes place through the roots the organism spreads throughout the plant by following up the woody portion inside the stem (fig. 3, *a*). Probably most of the infections, however, take place at the margins of the leaves, either through punctures made by leaf-sucking insects or in the small droplets of water which collect at the margins of the leaves during cool nights and in damp, rainy weather. The organisms then find their way into the interior of the plant.

It is not positively known how the organisms get to the points of infection on the leaf, but presumably they are carried there on the bodies of insects or lodged on the leaf from the dust in the air. The progress of the disease from the point of infection is inward and downward. It follows the bundles of the leaf. The portion of the leaf around the point of infection, except the fibrovascular bundles, first turns yellow, then brown, and finally dries up. The veins of an infected leaf are black. Infection may take place at several points on the same leaf and on several leaves of the same plant. In the course of time the disease advances to the base of the leaf and enters the stem, from which point it may infect many other leaves and work up through the center of the head.

[1] *Bacterium campestre* (Pammel) Erw. Sm.

YELLOWS (YELLOW-SIDES, WILT, DRY-ROT).

Description.—Infected plants usually show the characteristic symptoms of the yellows in two to four weeks after transplanting, but the disease may appear earlier in the seed bed. The parasite first injures the fibrous root system and thus stunts the plants and gives them a lifeless, yellowish green color. Sometimes the yellowing is uniform; more often it is worse on one side, causing a lateral warping or curling of stem and leaves (fig. 4). Early symptoms of the disease can be seen by cutting across the base of the stem, where the invaded vessels of the woody ring show a darker water-soaked color. This color deepens with the progress of the disease and the overlying tissues gradually die and collapse, resulting in a discolored sunken surface and the curving or warping of the stem already mentioned. The yellowed plants early shed their lower leaves while making a weak attempt to continue growth above. In the worst cases, death may result within two weeks or so after transplanting, but most of the plants continue a sickly existence for a month or more, and a few live through the summer, heading imperfectly (fig. 5). In these later stages when the interior blackening is most pronounced it may be difficult to distinguish yellows from black-rot; therefore the two diseases are often confused.

FIG. 4.—Cabbage yellows: A seedling plant dwarfed and leaves curled by one-sided infection. A normal plant of this age should be twice as large.

Control.—Disinfection of the seed (p. 7) reduces the danger of bringing the disease to new districts. The germs persist indefinitely in the soil, however, if once introduced. Sanitary measures and crop rotation are recommended, but these alone do not suffice to control yellows. Seed-bed infection is one of the worst dangers; hence, great care should be taken to plant the seed in clean soil. Steam

sterilization may be practiced to advantage by truckers, but, of course, for extensive field operations this can not be done. Even if perfectly healthy plants are transplanted into an infected field they may be attacked badly. The only safety, therefore, lies in either planting the crop on disease-free land or else in using only yellows-resistant varieties (fig. 6) as listed below.

FIG. 5.—Cabbage yellows, later stages: Where the plants are not attacked too severely or are somewhat resistant they may continue a sickly existence through the season. Such plants are yellowish and the lower leaves keep dying and falling. The attack is often worse on one side, warping or curling the stems.

In infected districts especial precautions are necessary to check the spread of yellows to new soil. Farm tools, animals, and surface water are common carriers, and a case is recorded where the disease was introduced by using infected drainage water when setting the plants.

Resistant varieties.—There is a marked difference in varietal susceptibility to yellows, and by selection highly resistant strains have been secured. The Volga and Houser are the hardiest of the older domestic varieties. The Wisconsin Hollander is a disease-resistant

selection from the standard winter variety Hollander and should be used wherever the winter crop is grown on "yellows-sick" soil. Commercial cabbage growers are urged to give attention not only to securing resistant strains but to improving them. Certain cabbage growers where "yellows-sick" soil occurs should make a practice of selecting the best types of healthy heads (fig. 7) from infected fields and from these grow seed for local use.

Only a limited supply of the yellows-resistant cabbage seed is as yet produced, and this is largely of the Hollander variety, adapted to Wisconsin conditions. Other varieties resistant to the disease must yet be developed in the various localities in which they are grown, and cabbage breeding for this purpose is now under way

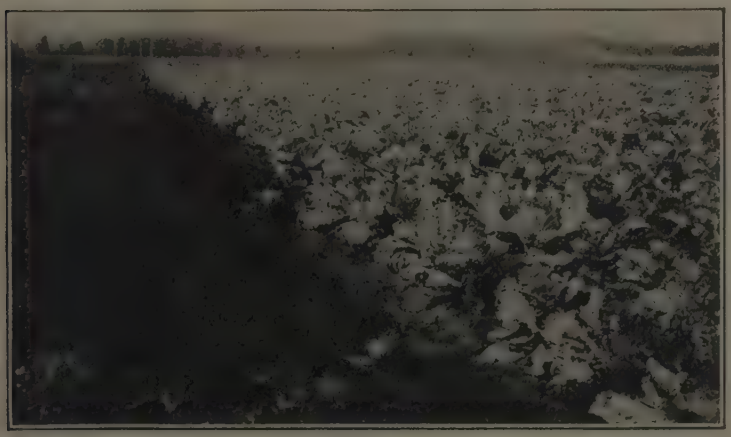

FIG. 6.—Cabbage yellows: Commercial Hollander, a nonresistant variety (on the left), showing only a few sickly plants still alive among the weeds. Wisconsin Hollander, a resistant variety (in the rest of the field), giving practically a full stand.

in several States. The growers wishing seed of resistant strains should write directly to the director of the experiment station in the State in which they reside.

Distribution and loss.—Cabbage yellows occurs seriously from Long Island to Iowa, including the southern parts of New York, Michigan, Wisconsin, and Minnesota, and southward as far as cabbages are grown as a summer crop. It is worse in warm, dry summers, and does little or no damage in the cooler extreme northern sections or along the northern Pacific coast, while the winter-grown cabbage of the Southern States also escapes the disease. In certain intensive cabbage-growing sections in the region indicated, especially in the latitude of New Jersey and Maryland westward to southern Wisconsin and Iowa, this disease has been rapidly increasing in

extent and seriousness. In bad seasons it may destroy 90 per cent of the crop and, indeed, is the limiting factor in success with cabbage as a field crop.

Cause.—Cabbage yellows is caused by a soil fungus.[1] This organism when once introduced seems capable of persisting indefinitely in favorable soils, although cabbage is not grown. The parasite requires high temperatures and even on the "sickest" soils it does not attack the cabbage until the soil warms up to about 60° F. or above, which in the Northern States means midsummer. This explains the variations in the seasonal and geographical distribution of the disease, cool, moist summers tending to lessen the loss and hot, dry seasons to aggravate it.

Infection takes place through the young roots, and it is especially injurious, therefore, immediately following transplanting, when the new root system must be developed.

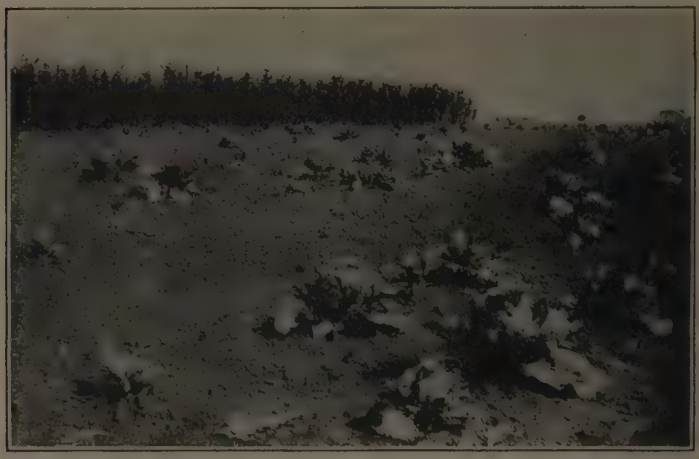

FIG. 7.—A field with "cabbage-sick" soil, most of the plants having been killed by the yellows. A few plants have withstood the disease and if such are selected for seed and the process repeated for several years a resistant strain may be secured.

The vegetative part of the fungus consists of minute, colorless threads called the mycelium. This develops rapidly within the stem and leaves, which are killed and discolored as it progresses from the young roots upward through the stem and leaves. By thus crippling or destroying the absorbing and conducting systems of the plant, gradual starvation results.

Three forms of reproductive bodies (spores) are known. One type is composed of colorless sickle-shaped bodies divided into two or more parts. These are formed on the surface of the dead cabbage plant. Another form is colorless, oval in shape, and often formed within the vessels of the host. A third type is roundish, thick-walled, and able to withstand severer weather conditions; hence, it is especially adapted for overwintering or wide dissemination of the fungus. It is probable that the fungus not only lives over on old

[1] *Fusarium conglutinans* Wollenw.

cabbage stumps but persists indefinitely on decaying vegetable matter in the soil, even producing its spores and disseminating itself in this way.

Closely related species of Fusarium cause numerous diseases of other crops. Among those well known and commonly met with are the dry-rot of potatoes, the scab of wheat, and the wilt diseases of sweet potato, flax, tomato, cotton, and cowpea. These diseases are, however, all distinct from that of the cabbage; hence, any of these crops may safely be rotated with cabbage.

BLACK-LEG (FOOT-ROT, WILT).

Description.—Black-leg is known as a destructive disease on only cabbage and cauliflower, although it may attack Brussels sprouts, kohl-rabi, collards, rape, kale, rutabaga, turnip, radish, sweet alyssum, and various related cultivated and weed plants of the mustard family. It may invade almost any part of the plant, but the worst damage occurs when it blackens and kills the stems of young plants in the seed bed or field; whence its common names.

FIG. 8.—Black-leg of cabbage, showing the death and blackening of the main root, with feeble development of the new side roots above.

The earliest symptoms may appear in the seed bed two or three weeks before transplanting time. Infection frequently occurs on the stem near the surface of the ground, causing dark sunken or irregular areas. From these spots the disease spreads, gradually killing the base of the stem and root (fig. 8), so that the plant wilts and perishes. Such wilting of the entire plant is characteristic of the advanced stages of black-leg, and the leaves adhere to the stem (see fig. 10), instead of falling off as in yellows. Frequently plants attacked by black-leg show a purpling of the leaves as the first conspicuous symptom, even before any wilting occurs. Often the disease may appear as dead spots on the older leaves or leafstalks, and with seed plants the spotting of the flowering branches and seed pods

is common. It is often difficult to distinguish the stem-rot caused by black-leg from maggot injury, the more so as the two often occur together. Certain other fungi also cause leaf spots resembling those of black-leg. (See pp. 28 and 29.) It is, therefore, important to note that the peculiar character of black-leg which serves to distinguish it is that in its advanced stage the dead areas are covered with minute black specks, like pin points (fig. 9). These are the fruiting bodies of the parasite (pycnidia) filled with the spores by which the disease is disseminated and overwinters.

Control.—The black-leg parasite is harbored in the soil by these fruiting bodies on fragments of the diseased stems and leaves, which may persist two or more years until the old stumps are fully decayed. It is common in seed fields, especially in the Eastern States and in Europe, and where it so occurs the seed may carry the infection. The most serious trouble arises from seed-bed infection, either from the use of infected seed or making the bed on infected soil. The first precaution, therefore, lies in seed disinfection (p. 7); the second, in the selection of clean soil for the seed bed. If old soil must be used, it should be steam sterilized where practicable (p. 7).

FIG. 9.—Black-leg of cabbage: A portion of a leaf showing injury at two separate places, in which numerous small black fruiting bodies of the organism are produced.

In case of bad developments crop rotation should be practiced, and in general sanitary measures are to be recommended. These involve such precautions as can reasonably be taken to destroy or keep from scattering diseased materials. It is a good practice to remove promptly and bury deeply or burn diseased plants, to be careful about scattering diseased plant leaves on noninfected land, and to restrain stock from roaming from infected to noninfected fields.

Distribution and loss.—Black-leg occurs very generally in the regions where cabbage has been grown for long periods. In the United States it is more common in the East and North than westward and southward, although it is reported from Alabama on cabbage, and from the Pacific coast regions (Oregon) on rape as well

as cabbage. It is to be expected sooner or later wherever intensive cabbage culture is established.

The loss is ordinarily small if proper precautions are taken as to sanitation, seed bed, and rotation. Where these are disregarded the loss may range from 5 to 10 per cent up to 50 to 100 per cent of the crop (fig. 10).

Cause.—Black-leg is caused by a parasitic fungus.[1] This may be carried with the seed and persists in the soil. The first infections commonly take place in the seed bed, more often in the stems than on the leaves. Maggot or other insect injuries favor these, although infection occurs readily in the absence of wounds. The rate of development varies widely with temperature and moisture, but as a rule the parasite kills and discolors spots on stems or leaves, and within two weeks these are usually thickly studded with numerous black specks about the size of a pin point. In these black bodies are contained the spores, which are

FIG. 10.—Black-leg of cabbage, causing the wilting and dying of the lower leaves and a loss of over 75 per cent of the crop in a field.

small and colorless and upon oozing out are distributed by water, wind, insects, and other agencies to healthy leaves and new plants. Wet weather is favorable to the rapid spread of the disease, while the occurrence of maggots or flooding with water increases the liability.

SOFT-ROT.

Description.—Soft-rot of crucifers is characterized by a soft, mushy, almost slimy decay, which after entering, generally at the crown or root tip, spreads rapidly throughout the whole plant. The soft-rot bacteria as a class are marked by their ability to destroy

[1] *Phoma lingam* (Tode) Desmaz.

plants very quickly under favorable temperature conditions. They seldom affect uninjured plants, but require a wound or other injury to gain a foothold. Infection takes place in the field, where considerable damage has been occasioned, but the greatest destruction to this crop is caused in the cabbage storage houses. Under improper storage conditions the disease spreads rapidly, frequently covering all the outer leaves. The slime formed under these conditions is very unsightly and consequently affects the market value, even though only slight injury is caused.

Control.—Fields where the disease is known to occur should be avoided and rotation practiced with crops not injured by soft-rot organisms. It has been found that in storage houses, where the maximum loss occurs, an increase of the temperature much above the freezing point and a high percentage of humidity will result in rapid decay. In view of this fact it is advisable that a temperature uniformly 1 or 2 degrees above freezing should be maintained and the relative humidity kept near that of the outdoor air by careful ventilation. Furthermore, cabbage and other crops when going into storage should be handled carefully, so that they will be injured as little as possible. Since the soft-rot organisms are especially sensitive to light and drying, the crop should be thoroughly dried in the sunshine before being put into storage.

Distribution and loss.—The loss from soft-rot is considerable, especially in storage houses, where 25 to 50 per cent or more of the crop has been destroyed in a single season. The greatest loss occurs in New York and Wisconsin, where the storage of cabbage forms an important industry.

Cause.—Soft-rot in cabbage and related crops is due to bacteria belonging to a group usually referred to as the soft-rot bacteria[1] which may attack carrots, turnips, celery, and other vegetables.

ROOT-ROT (WILT).

Cabbage is frequently grown on rather heavy flat land which is not well drained. Under these circumstances heavy rains may cause surface flooding, especially in any low spots. Where this occurs in midsummer, so that the ground is covered or saturated with water for a few days, especially if followed by hot, sunny days, the fibrous roots are soon drowned or killed from lack of oxygen. Such roots quickly rot, the leaves wilt, and the plants die. It is, of course, important not to confuse the wilting from this cause with similar wilt due to either of the two parasitic diseases already described, clubroot and black-leg.

[1] *Bacillus carotovorus* Jones is a typical example.

MALNUTRITION, A PHYSIOLOGICAL DISEASE.

Malnutrition is a trouble which affects cabbage, cauliflower, and other crops, especially in the Southern States. It is quite different from any of the diseases previously discussed, all of which are caused

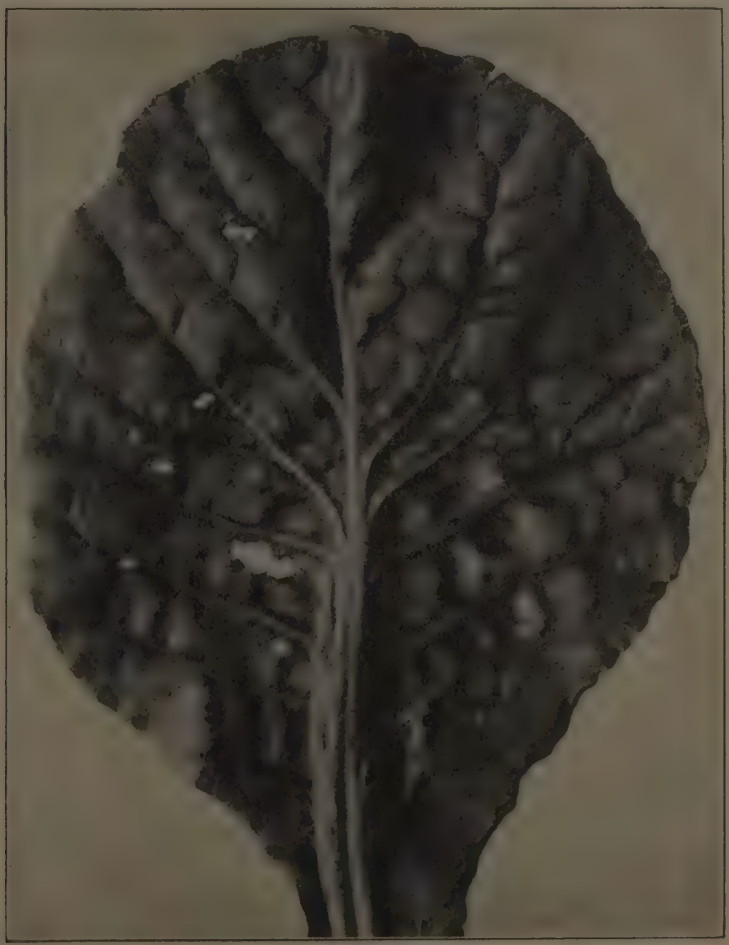

FIG. 11.—A cabbage leaf showing the characteristic symptoms of malnutrition. Between the veins the tissue is a light yellow.

by parasites. By malnutrition is meant a disturbance of the normal functions of a plant, which may be a result of its inability to obtain the proper nutrient substances from the soil. Malnutrition may be

caused in several ways, such as the excessive use of mineral fertilizers, the lack of humus, or the accumulation of acids in the soil.

Description.—The most characteristic symptom of malnutrition is a change of the normal green of the leaves to a light green or yellow between the veins and around the margins. (See fig. 11.) The lower leaves are the first to show symptoms; then the upper and inner ones. All diseased leaves are perceptibly thickened and so brittle as to be easily crushed between the fingers.

The heads from plants slightly affected are small and immature; when plants are badly diseased no heads are formed.

The roots are small and the lateral feeders few in number and frequently dead at the extreme end. Often the epidermis of the stem at the surface of the soil is injured, closely resembling the corrosive action of some acids and alkalis.

Control.—In controlling malnutrition, four points need consideration: (1) The limitation of the quantity of fertilizers used; (2) the adjustment of the composition of the fertilizer to meet the crop requirements; (3) the rational use of lime; and (4) the maintenance of the organic matter of the soil.

The practice of farmers tends to increase the quantity of fertilizers when the preceding crop was poor, in the belief that the yield can in this way be maintained. This practice is not always the best. As a result of experiments on early cabbage in Viriginia it was shown that better yields could be obtained from 1,000 pounds per acre of mineral fertilizer than from any larger quantity up to 4,500 pounds, which gave the smallest yield of all.

The composition of the fertilizer or the ratio of the different substances composing it should be such as to give an alkaline rather than an acid reaction, for acid soils have been found to increase and alkaline soils to decrease the severity of the malady. As malnutrition is worst on acid soils, air-slaked lime at the rate of 1,000 to 2,000 pounds per acre should be added. Among the more important effects of liming soil the following may be mentioned: (1) To render available certain forms of plant food, especially compounds containing potassium; (2) to facilitate the decomposition of organic matter by encouraging the growth of microorganisms; (3) to promote the growth of organisms that gather nitrogen from the air; and (4) to improve the physical texture of the soil.

Many of the old cultivated fields of the South are ordinarily deficient in humus or organic matter, a condition for which mineral fertilizers are largely responsible.

Humus can be supplied to such a soil by the use of stable manure or by growing green-manure crops, such as cowpeas, soy beans, vetches, etc., to be turned under when mature. The results from this

method of restoring natural fertility to the soil are ordinarily very marked on the first succeeding crop.

Distribution and loss.—Malnutrition diseases are confined principally to those localities where mineral fertilizers are used in order to produce larger and earlier crops. The disease, therefore, is restricted mostly to the Southern States. In general these soils are poor, respond quickly to fertilizers, and have been intensively and carelessly farmed for many years. The loss from this trouble, though large, can not be accurately estimated.

Cause.—Constant, clean cultivation for many years has robbed the soil of most of its original fertility. The farmers, therefore, naturally turned to the use of commercial fertilizers as a substitute. The results for many years were very gratifying. At the outset better crops were obtained than was possible on the best soils without fertilizers. This led the farmers to believe that fertilizers alone were necessary on any soil and the more used the greater the yield. When the returns decreased as a result of this practice the quantity applied was gradually increased until it was not uncommon to add as much as 3,000 pounds of mineral fertilizers per acre for a single crop of cabbage. A large part of the fertilizer applied was not used by the plants, but remained in the soil, where in the course of a number of years a considerable quantity accumulated.

It is a well-known fact that the salts comprising mineral fertilizers are poisonous to plants when used in excessive quantities. Some fertilizers have an acid reaction and eventually cause what is popularly known as "sour soil." On the other hand, a small quantity of acid in the soil is not generally injurious, but it is not uncommon to find soil in the South so acid as to require 5,000 to 9,000 or more pounds of lime per acre to neutralize it. No agricultural plants will give their best yield under such conditions.

Briefly summarized, malnutrition in truck crops is caused by the excessive use of mineral fertilizers and the exhaustion of the humus of the soil.

DOWNY MILDEW.

Description.—Downy mildew first appears in the spring as a whitish mold in isolated spots on the undersides of the leaves. It may also occur on the stems. At the close of the season the portion of the leaf immediately surrounding the diseased area appears yellow and later turns brown and dries up. Frequently, light areas are observed in the center of a dark ring, which in turn is surrounded by a light or yellow area, thus presenting a conspicuous mottled appearance.

Control.—Downy mildew is seldom so troublesome as to require remedial measures. It is likely that most cruciferous weeds are attacked by this organism. Such weeds are sources of infection to cabbage and related crops and should be kept down. Any plants found diseased in the seed bed should be destroyed, not planted. The remains from diseased plants should be destroyed, as they serve to carry the resting spores over the winter. Crop rotation should be practiced. The plants should not be grown too thick or kept too wet in the seed bed. If, in spite of such precautions, the mildew is

serious, the plants in the seed bed should be sprayed about once a week with Bordeaux mixture (4–4–50 formula).[1]

Distribution and loss.—Downy mildew seldom causes any serious loss except in seed beds. It has been found in Australia and Europe and has been reported from several States in the United States. It undoubtedly occurs wherever cabbage is grown, but owing to the fact that it causes but little loss to the crops it has not been reported.

Cause.—Downy mildew[2] attacks all crucifers and causes distortions and abnormal growth. Two forms of reproductive bodies are produced. In one of these spores are developed in the air on the surface of the host, forming a visible down coating. When these spores germinate, the germ tube enters the tissue of the host and a new infection is started. These reproductive bodies are formed in great numbers and are readily carried from one plant to another by a gentle breeze or by insects. The disease is carried through the winter by means of yellowish, thick-walled bodies which are able to withstand unfavorable conditions until spring, when they germinate and reestablish the disease.

WHITE-RUST.

Young plants are more subject to attack, but the damage to cruciferous crops from white-rust is ordinarily very slight. The disease may occur on any part of the plant above ground, but more frequently on the leaves, where the tissue is often stimulated to distorted and abnormal growth. Moist, cloudy weather furnishes suitable conditions for the spread and growth of this disease.

Control.—Control measures are rarely necessary; if required, spray the plants in the seed bed once each week with Bordeaux mixture (4–4–50 formula[1]). The seed bed should not be kept too moist. Set only healthy plants in the fields and destroy all others.

Distribution.—White-rust is distributed throughout the world and is found on all crucifers. Apparently, however, it does not spread from the common wild mustards of America or from radish to cabbage. This indicates that there are specialized races or forms of the parasite and may account for the fact that the disease is not found as widespread on cabbage as on most other related plants.

Cause.—The disease is caused by a fungus[3] which enters the tissue of the host through the stomata, or breathing pores. Small oval spores are formed, which are attached one to another in a beadlike manner under the surface. They finally escape and are then easily wafted by the wind or carried on the body of insects to other plants. In the presence of sufficient moisture and at low temperatures they readily germinate, and the fungus enters the stomata, or breathing pores, if lodged on the proper host. The disease is carried through the winter by the formation of bodies within the tissue of the host, from which they are set free the following spring by the decay of the plant.

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[1] This formula is 4 pounds of copper sulphate (blue vitriol) and 4 pounds of stone lime to 50 gallons of water.

[2] *Peronospora parasitica* (Pers.) De By.

[3] *Albugo candida* (Pers.) Ktz.

DROP.

Description.—The earliest symptoms of the disease known as drop are indicated by water-soaked areas over the stem and lower leaves. This wilting of the lower leaves is followed by the whole plant collapsing finally into a shapeless mass. The plant may succumb to the disease in a few days, or it may live from one to two or more weeks. In and about the decayed region a dense, white, cottony mass of mycelium accumulates. In the later stages of the disease irregularly shaped, hard, black bodies, about the size of a mustard seed, are to be found scattered among this cottony mass. These bodies are almost sure evidence of the disease.

Control.—This fungus is best known as the cause of the lettuce drop. It also causes a serious disease of the cucumber, carrot, and potato, of various bulbs, and of other plants. In view of this fact, care should be taken in the rotation not to follow lettuce with cabbage on fields where the drop has occurred. It is further advisable, when possible, to pull up and destroy infected plants. Compost which may contain the refuse of lettuce, cabbage, and other crops that have been destroyed by the fungus should not be used on cabbage beds or in the field.

Distribution and loss.—The cabbage drop is worst along the Gulf coast region. During some seasons the disease causes heavy losses to the crop in southern Alabama and parts of Florida and Texas. Though its distribution has not been thoroughly studied, it is likely that the disease occurs in other States as well.

Cause.—The drop is caused by a fungus[1] made up of a coarse, white, fungous growth which forms in and about the decayed region of the host. Later the hard, black bodies mentioned above develop from the mycelium.

SPOT DISEASE OF CAULIFLOWER.

The spot disease was first found to attack the leaves of cauliflower, but later was observed on cabbage to a more limited extent. It causes on the lower surface of the leaf, and less abundantly on the upper, small brownish to purplish gray spots (fig. 12) somewhat irregular in outline. A puckering of the leaf results when the midrib and larger veins are badly affected.

Some loss was caused to cauliflower in tidewater Virginia during the spring of 1911, where 25 to 90 per cent of the plants in the worst cases were attacked.

This is a new disease of cauliflower and cabbage, due to a bacterium, and no means for its control have been worked out. It has been observed that the spot disease is most severe during cool, damp weather, and is held in check when the warm, sunny days of late spring come on. In view of the fact that the organism is especially

[1] *Sclerotinia libertiana* Fuckel.

sensitive to sunshine and warm weather, it is not likely to cause any serious damage except during protracted rainy, cool weather. Crop rotation should be employed in controlling it. So far as known, the organism causing the spot disease of cauliflower and cabbage does not attack any other crucifers.

FIG. 12.—Upper surface of a cauliflower leaf, showing typical injury caused by the spot-disease organism.

BLACK LEAF-SPOT (BLACK MOLD).

Description.—The black leaf-spot fungus may attack the cabbage plant at any stage of its growth, but is not common except on the older leaves in the field or on heads in storage. In the field it appears on the lower or outer leaves of the maturing plants as distinct, roundish, black spots, commonly marked with concentric brown zones (fig. 13). These spots vary from one-fourth to one-half an inch or more in diameter. In storage these spots may blend together until the outer leaves are covered and entirely blackened by the moldy development.

Control.—To prevent loss from this fungus in the storage house the following suggestions should be observed: (1) Disinfect the storage house by spraying the walls, benches, and bins with Bordeaux mixture; (2) exercise care in handling, so as to minimize injury to the heads; (3) maintain a temperature 1 or 2 degrees above freezing; and (4) keep the humidity as low as possible by proper ventilation of the house with outside air.

Distribution and loss.—Black leaf-spot causes considerable damage to cabbage and collards in this country and in Europe. The greatest loss to cabbage occurs in the storage houses. The organism causing the disease is present in the houses under ordinary conditions, or it may be carried there with the cabbage when it goes into storage. It gains access to the tissue through wounds made by handling and cutting or by following up the tissue killed by other organisms. In the presence of plenty of moisture and a suitable temperature it develops rapidly, forming an unsightly black mold over the heads.

Cause.—The commonest form of black leaf-spot is due to a fungus,[1] but other related fungi may cause similar leaf spotting and other fungi contribute to the molding in storage.

POWDERY MILDEW.

Powdery mildew is caused by a parasitic fungus[2] which forms a white powdery dust on the leaves of turnips, cabbage, and a few other plants. The loss caused by this disease is so slight that treatment is unnecessary.

DAMPING-OFF.

Damping-off is a disease of young seedlings and may be caused by any one of several species of fungi. It occurs mostly in the seed bed, where plants are growing in a crowded condition. It is rarely found in the open field. It is also a common disease in greenhouses, where a relatively high humidity is maintained and where the plants are protected from sunshine and free circulation of the air. The disease usually attacks the seedling on the stem at the surface of the soil soon after it comes through the ground. It soon girdles the stem and destroys the epidermis. The plant finally topples over and dies.

FIG. 13.—Black leaf-spot of cabbage; characterized by concentric rings.

Preventive rather than curative measures should be employed for this disease. Since it may result from spores carried on the seed, it is best to disinfect the seed (p. —) as a general precaution.

If damping-off has occurred before, the soil should not be used again, or if used should be sterilized in accordance with one of the methods already discussed. Any method that will prevent the accumulation of too much moisture in the surface soil and reduce the relative humidity of the air about the plants is advantageous in preventing damping-off. This can be accomplished by practicing the following suggestions: (1) The upper layer of soil should be frequently stirred; (2) a free circulation of air about the plants and exposure to sunshine should be permitted; (3) the plants should be watered in the morning in preference to the late afternoon or evening; and (4) a layer of fine, heated sand should be sprinkled over the surface of the soil.

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[1] *Alternaria brassicae* (Berk.) Sacc. [2] *Erysiphe polygoni* DC.

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